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Assessment of present conventional and non-conventional energy scenario of Pakistan

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ABSTRACT

It has become the universal fact that the energy is one of the key factors for the smooth and faster upgradation of the socio-economic activities in any country. In Pakistan's history of over 60 years, the country presently is facing possibly the worst energy crisis that has geared back the socio-economic development below the level of critical sustainability and tolerance of the people. Every walk of life and industrial activities have declined due to long electricity shut-down every day since last few years. In view to access the current status of available energy resources, the present research study has been carried out to review and assess the demography of the country versus energy sectors, energy supplies & consumptions, status of fossil-fuel resources (oil, gas & coal), conventional & non-conventional electricity generation, and past, present & future energy demand-supply during 2001–2011. The results of this assessment indicate that conventional resources in Pakistan are and will not be enough to meet the ever growing energy demand and consequently highlight the importance of the renewable energy sources that are apparently encouraging in the country but have not been developed to any satisfaction. Priority is imperative to be given for the adequate development of renewable energy sectors in addition to the present energy mix.

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1. Introduction

In view of the new millennium challenges for the modern faster socio-economic upgradation and adoption of new lifestyle, the industrial development seems to be at a very high demand as revealed from the on-going energy consumption and its

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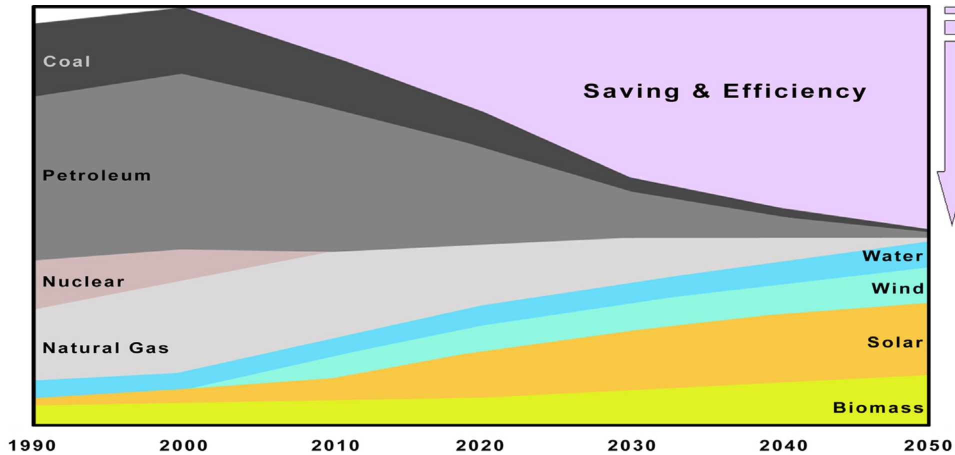


Fig. 1. Plots showing trends in adopting the energy sources since history to future.
Data Source: [1].

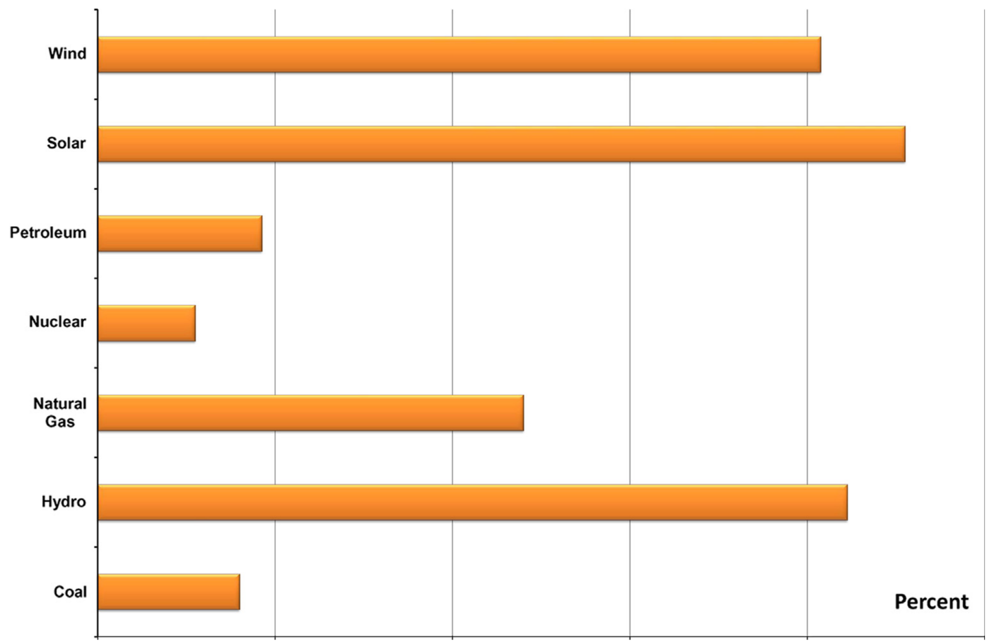


Fig. 2. Global consensus regarding the choice to adopt the energy generation sources.
Data Source: [3].

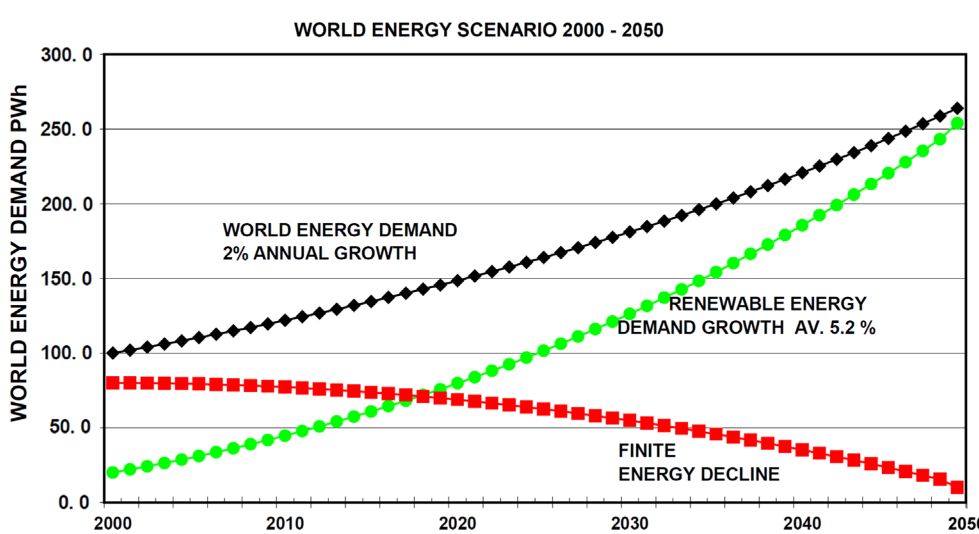


Fig. 3. Plots showing world energy scenario since 2000–2050.
Source: [7].

anticipated energy requirements as a whole in developed countries in general and in developing countries of the world in particular. It appears that energy demand will keep increasing but the conventional sources for generating electricity will deplete with time or may become environmentally hazardous enhancing global warming. Due to deplete of coal, petroleum and natural gas reserves and/or associated world politics, the nuclear energy source is also being considered as one of the alternate by the developing countries but because of its hazardous issues, relatively higher expenses and technological monopolies, it is not approachable for most of the countries of the world. Anticipating this decline, other non-conventional options, like wind, solar, biomass, geothermal, etc. are being given preferences as alternate and long-lasting sources of energy generation (Fig. 1) [1,2]. This rational approach is environmental friendly and free from the danger of producing pollution and health hazards of the people.

Considering the global opinion regarding the adoptability of the various energy generation sources, the solar energy is on the top choice of the countries rich in sunlight [3,4]. Hydel, wind, natural gas, petroleum, coal and nuclear sources of energies are afterward, depending upon the resources of the country. The conclusions arrived by Elektrizitatswerke (1998) for the use of possible energy sources in future also indicate the viability of renewable energy sources over the thermal (oil, gas and coal) and nuclear options (Fig. 2).

Some of the present statistical analyses show that the anticipated conventional energy generation sources of the world do/will not match with the energy demand, which is growing at a rate of 2% annually [5,6]. The renewable energy demand is growing at 5.2% annually that is almost more than two times of the present and projected world energy demand. It is also probable that sometime around 2050, the renewable energy growth will be equal to the world energy demand (Fig. 3) [7].

The present paper describes the salient features of the demographic variability in Pakistan; the review of country′s current conventional energy resources; the sector-wise energy production and consumptions; the electricity generation and demand–supply scenarios; and the status of non-conventional renewable energy options in Pakistan.

2. Demography of Pakistan

The Southeast Asia including Pakistan is facing a dramatic and rapid demographic transition over the last 35 years when its share of working-age population or savers (age 25–59 years) increased from 35% to 50%, and that of young population (0–14 years) declined to an average of 25% [8]. The empirical evidences suggest that a large part of Southeast Asia's spectacular economic growth derived from this demographic transition or working-age population bulge. This transition from a young to prime age population represented a demographic gift compared with earlier periods. In countries where an increasing share of the population is of working age, the economic growth per person tends to be higher and national saving rates tend to rise. As a result of this transition, the people are richer and have better access to health and education facilities than 25 years ago [9].

At present, there is a strong possibility that Pakistan may be benefited from the same demographic transition. However, over the last two decades Pakistan has seen only 2% increase in working-age population and 1.5% decline in the share of old age population (age 60+) [8]. While demographic transition provides an opportunity for raising economic growth and increasing prosperity in Pakistan, which will actually depend on acquisition of more energy from renewable sources in future to develop socio-economic policies for raising living standard, industrialization, education, job opportunities, and mobilizing sufficient investment.

According to the census of 1951, Pakistan's population was 33.8 million. By the end of June 2011, the population is estimated to have reached 177.1 million [10–13]. Thus, in roughly two generations, Pakistan's population has increased by 143 million or has grown at an average rate of 2.8% per annum. Pakistan is now the seventh most populous country of the world where the distribution of population is uneven in the provinces. Its population rate is considered to have slowed in recent years from an average of slightly above 3–1.88% in 2007.

Considering the rapid increasing trend in population, the growth trend of energy generation should have been proportionally maintained to achieve the targets set for the country, but it is not the case. It is because of lack in planning for the energy generation and the development capabilities for rational identification of energy sources during the last 60 years.

3. Review of Pakistan's energy sectors

Since the energy sector plays a key role in the development and growth of the economy, Pakistan needs adequate supplies of energy to generate healthy economic activities. The main objectives of the energy sectors should be to ensure adequate, secure, and cost-effective supplies to industries, agriculture, transportation, domestic needs, etc. by utilizing all available resources efficiently and minimizing its losses. The Government of Pakistan though has identified energy as one of the major drivers of the economic growth [14], the renewable energy has not yet been given due importance, though Pakistan is a sunny country all the year round and the wind is appreciably of high potential. It is also true that energy can be obtained from renewable sources at low cost without any hazardous possibilities.

The present effort of the government is to speed up the development of energy resources out of coal reserves and hydel power projects, in addition to secondary consideration of utilizing wind energy as well.

In prospective areas for the construction of new dams, the government needs to consider differences in the provincial political opinions, the possible hazards of environment and reclamation of land where salinity & water-logging problems may arise. It is also important in considering the development of energy creation and procurement that huge financial and foreign technical assistance could be required in developing hydel and nuclear energy establishments. On the contrary, clean energy generation from solar, wind, geothermal, biomass sources can be obtained at relatively less expense [15] and would also be free from any environmental hazards. The energy procured can well be utilized in all walks of life including industrial and commercial establishments.

An attractive policy package for petroleum and power was announced by the Government for the elimination of electric power shortage by mobilizing the existing resources, promoting private sector investments (domestic and foreign) and enhancing indigenous oil and gas production [16]. Subsequently, the Ministry of Environment, as a follow-up of the World Summit for Sustainable Development (WSSD) also initiated a nationwide stakeholder consultation to develop the National Energy Conservation and Renewable Energy Strategy for Pakistan [17].

The implementation of the above policy facilitates in exploiting the existing energy resources to build a strong indigenous exploration and production base. These efforts would be directed to achieve cost effectiveness, reduction in import dependence, promotion of self-reliance through accelerated exploitation of energy resources and minimum environmental degradation.

3.1. Energy supplies and consumption

Pakistan's total primary energy supplies estimated to be around 64.5 Million Tons of Oil Equivalent (MTOE) in 2010–2011 [18], include conventional and other sources of energy like wood, cow-dung and to some extent biomass those are in common use especially in rural areas [19,20]. Conventional sources such as oil, gas, liquid petroleum gas (LPG) and coal contribute about 88.1% of the national primary energy supplies. Natural Gas with a contribution of 47.6% and about 30.7 MTOE to primary energy supplies and an average compound growth rate of 5.1% during 2001–2011. It is the major primary energy supply resource in the country. Oil constitutes about 32.0% of the total primary energy supplies of the country, of which only about 31.9% is met through indigenous production. Fig. 4 shows primary energy supplies by source as percent share and in TOE in the country for the period of 2001–2011.

The final energy consumption of the country was about 38.8 MTOE in 2010–2011 and was accordingly dominated by gas and oil, and account for 43.2% and 29.0% of the total national energy consumption respectively. Fig. 5 indicates energy consumption in the country for the period of 2001–2011.

4. Fossil-fuel energy resources of Pakistan

4.1. Oil resources

Oil accounted for 32.0% of primary energy supplies and 29.0% of final energy consumption of Pakistan during 2010–2011. Crude oil reserves available in different oil fields of Pakistan as on June 30, 2011 were about 306.6 million barrels out of 944.3 million barrels of total reserves [18]. Twelve different operator companies are

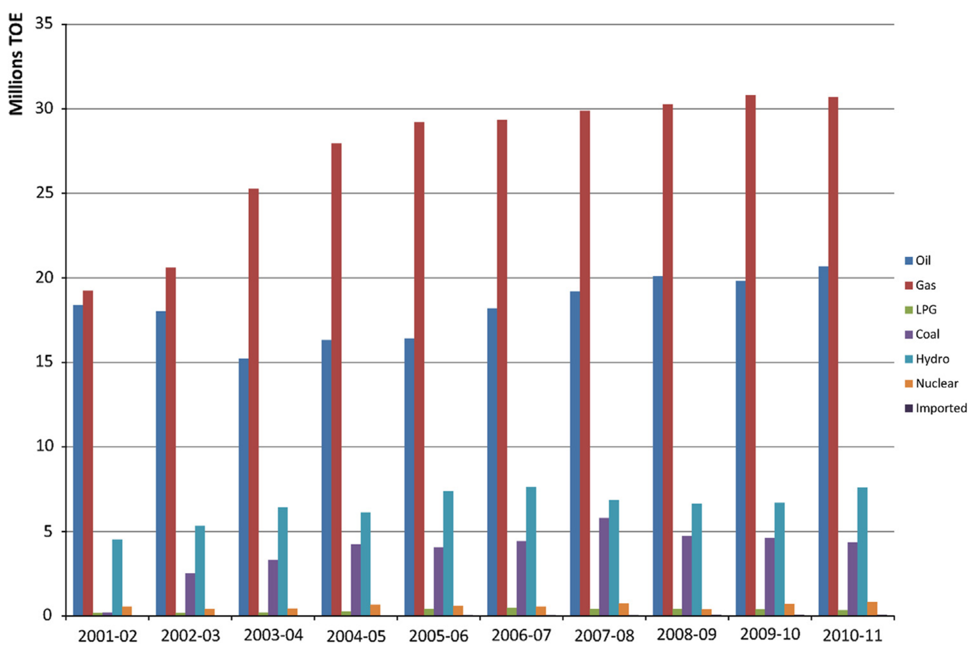


Fig. 4. Primary energy supplies of Pakistan (in Millions TOE) from 2001 to 2011. *Data source*: [18–23].

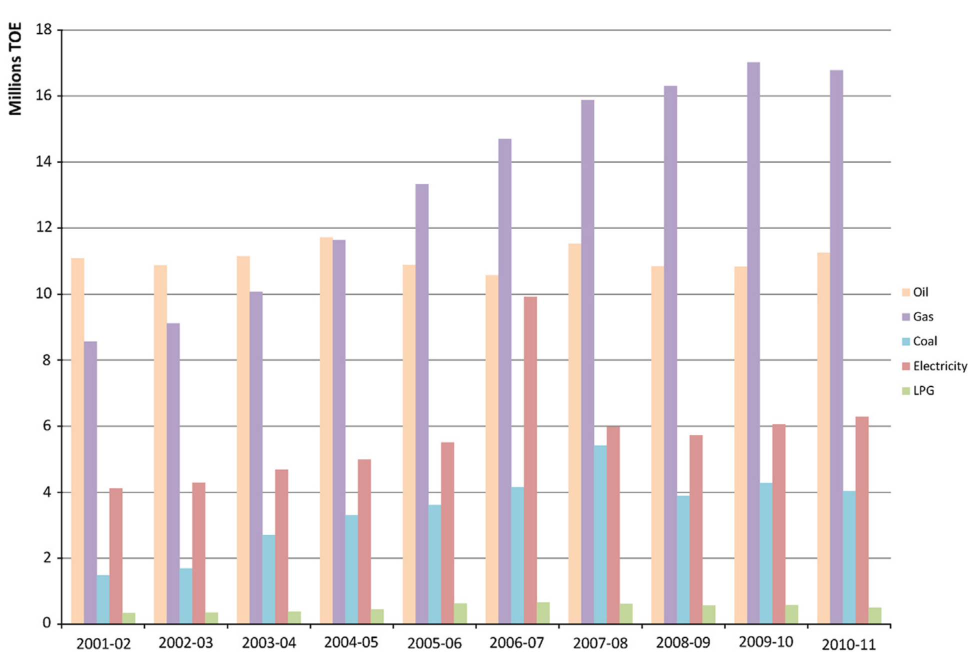


Fig. 5. Final energy Consumption of Pakistan (in Millions TOE) from 2001 to 2011. *Data source*: [18–23].

involved in crude oil production from around 133 oil fields developed so far in the four provinces of Pakistan. Oil & Gas Development Company (OGDC) has the highest share of about 55.9% in indigenous crude oil production during 2010–2011, followed by BP Pakistan Exploration & Production Inc. and MOL Group having a share of about 12.7% and 11.4% respectively.

About 68.1% of total crude oil supplies during 2010–2011 were met through imports. The country's expense on crude oil imports during 2010–2011 stood at US$ 4.69 billion. Fig. 6 provides details in respect of crude oil imports for the period of 2001–2011.

There are seven petroleum product refineries in the country with a total refining capacity of about 13.2 million tons per year. In addition, the country imports a substantial amount of petroleum products, which is one of the main components for causing economic burden on the nation. The imports related to petroleum products were to the order of 12.5 MTOE during 2010–2011. Fig. 7 provides details in respect of imports of petroleum products in the country during the period of 2001–2011.

Transport sector consumed 48.9% of total petroleum products during 2010–2011 while shares of power sector and industrial

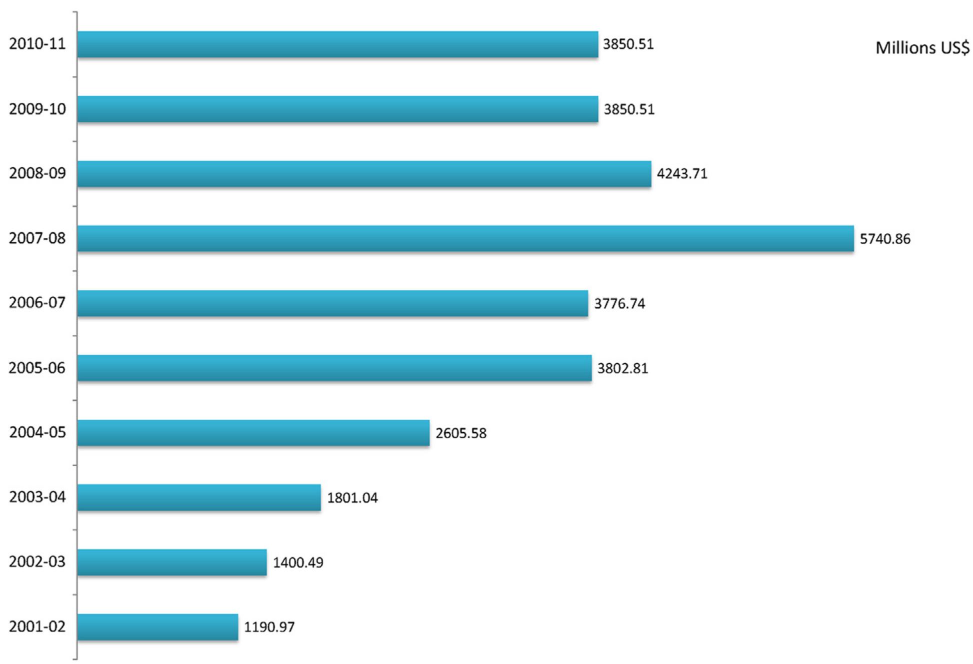


Fig. 6. Expenses on the import of crude oil (in Million US$) during 2001–2011.
Data source: [18–23].

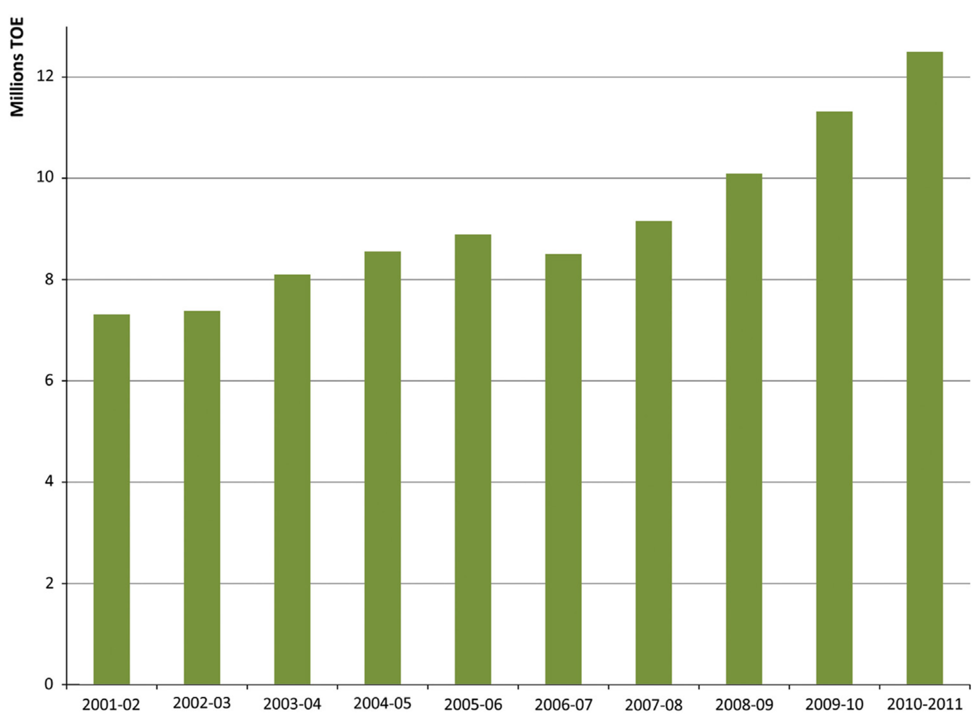


Fig. 7. Import of petroleum products (in Millions TOE) during 2001–2011.
Data source: [18–23].

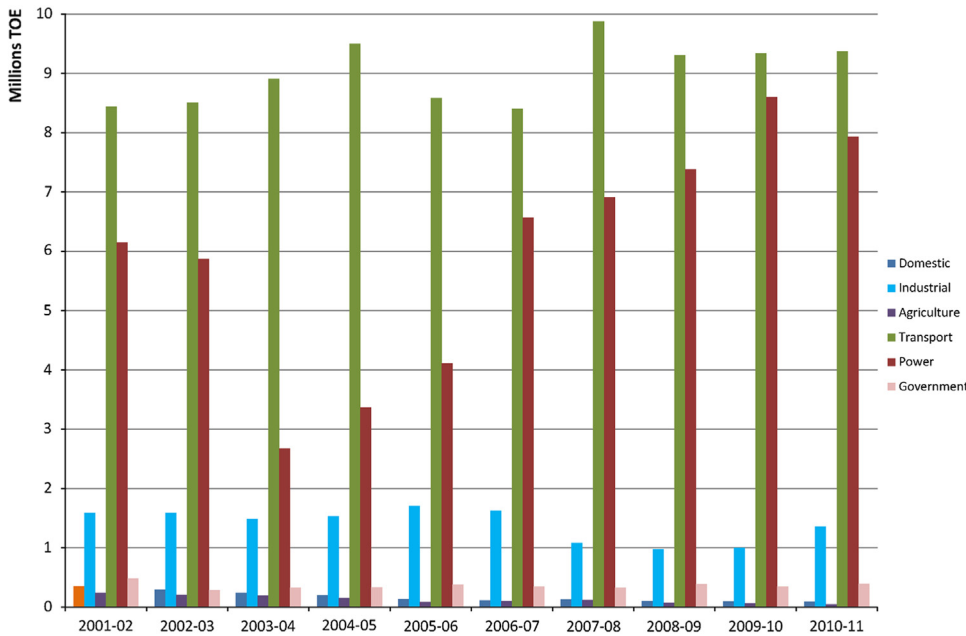


Fig. 8. Petroleum products consumption of Pakistan (in Millions TOE) during 2001–2011.
Data source: [18–23].

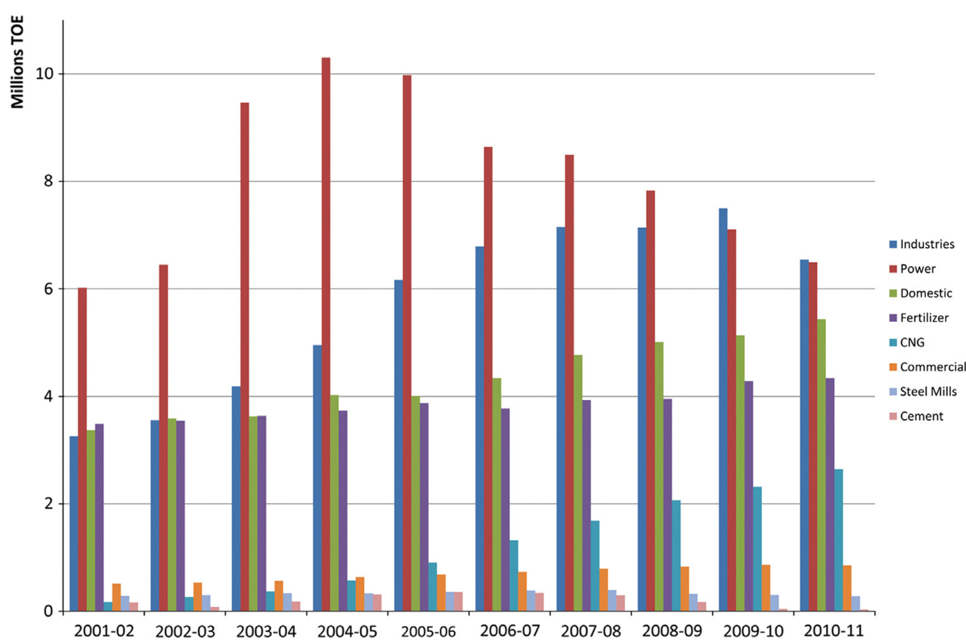


Fig. 9. Natural gas consumption of Pakistan (in TOE) from 2001 to 2011.
Data source: [18–23].

sector during the same period were 41.3% and 7.1% respectively. Share of different sectors in the consumption of petroleum energy products during last decade is provided in Fig. 8.

4.2. Natural gas resources

Natural Gas accounted for 47.6% of primary energy supplies and 43.2% of final energy consumption of the country during 2010–2011 [18]. Total recoverable gas reserves available in the country as on June 30, 2011 were 55.1 trillion cubic feet (TCF) equivalent to 1085.3 MTOE, from which only 27.5 TCF has been remained in balance. Sui is the largest gas field in the country with original recoverable reserves of more than 12.7 trillion cubic feet.

General industry sector consumed 24.6% of total natural gas during 2010–2011, while shares of power generation, domestic consumption and fertilizer plants during the same period were 24.4%, 20.4% and 16.3% respectively. Fig. 9 presents natural gas consumption by various sectors of economy during the period of 2001–2011.

4.3. Coal resources

Pakistan has huge deposits of coal. Most of the coal reserves in the country need mechanized mining and exploitation. Presently, the largest discovered reserve is located at Thar Desert of Sindh province, which is to be exploited and developed. However, the production of coal from different parts of Pakistan has decreased to 3.45 million tons per annum (about 1.5 MTOE) in 2010–2011

from 3.48 million tons with an annual compound growth rate of −6.7% [18–23].

Cement and other industries consumed 61.6% and power sector consumed only 1.0% during 2010–2011, while 30.9% was consumed by brick kilns sector.

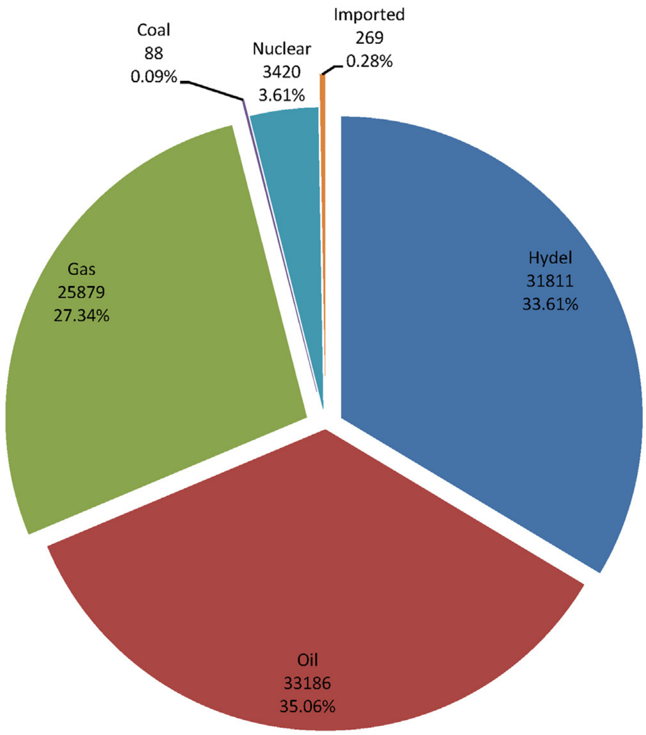


Fig. 10. Electricity generation of Pakistan (in GWh and percentage) during 2001–2011. *Data source*: [18–23].

Table 1
Share of hydel and thermal power generation for the last 10 years (in TWh). *Data source*: [18–24].

Year	Hydel power generation	Thermal power generation
2001–02	18,941	51,174
2002–03	22,351	51,591
2003–04	26,944	52,122
2004–05	25,671	57,162
2005–06	30,862	60,283
2006–07	31,953	63,972
2007–08	28,707	63,877
2008–09	27,784	62,214
2009–10	28,093	64,371
2010–11	31,811	59,153

5. Electricity generation in Pakistan

Total installed capacity of electricity generation in the country as on June 30, 2011 was 22,477 MW with 94,385 Giga Watt Hour (GWh) of gross generation (Fig. 10) with thermal, hydel, and nuclear taking 62.7%, 33.7% and 3.6% share respectively during 2010–2011 [18]. The independent private power producers (IPPs) contributed about 62.9% of the total thermal generation in the country during 2010–2011. Share of oil and gas in the thermal power generation during 2010–2011 stood at 56.1% and 43.7% respectively. There is a consistent growth in the consumption of electricity from 74,348 GWh in 2009–2010 to 77,099 GWh in 2010–2011 with an annual growth rate of 3.7% due to increased urbanization, development of electricity grid for supply to larger areas and rural electrification program. The government has announced an attractive policy package for petroleum and power for eliminating power shortage, mobilization of available resources and promoting domestic & foreign private sector investments.

The share of hydel power in total generation has been gradually declining since 2000 as the water storage capacity of the existing reservoirs is reducing by silting and no new hydel generation facilities were setup. As a result, share of thermal generation has been gradually increasing during this period at the cost of imported petroleum products (Table 1). This situation is creating tremendous pressure on the economic growth as well as on the sustainability of healthy environmental conditions in the country, particularly in the urban centers.

The optimal utilization of hydroelectric potential is accorded priority in the overall power development program. The new hydel projects that were announced by the President of Pakistan under Vision-2025 Program include (i) Diamer Basha Dam with total installed capacity of 4500 MW (average generation of 19,208 GWh/year) and excepted to complete in 2020–2021; (ii) Munda Dam with installed generation capacity of 740 MW and planned to complete in 2018; (iii) Akori Dam with installed hydel based generation capacity of 600 MW (equivalent to power generation of 2155 GWh/year) and expected to commission in 2016; and (iv) Kurram Tangi Dam with 83.4 MW generation capacity and expected to complete in late 2015 [24]. Feasibility studies of other hydel based power generation projects are also in progress under Water & Power Development Authority (WAPDA) namely Bunji Dam (7100 MW), Dasu Dam (4320 MW), Thakot Dam (2800 MW), Patan Dam (2800 MW), Lower Palas Valley Dam (665 MW), Spat Gah Dam (496 MW), Keyal Khwar Dam (122 MW), Golen Gol Dam (106 MW) and Phandar Dam (80 MW).

Nuclear power generation technology is a sophisticated, advanced, and multi-disciplinary system and only few neighboring countries like China, India and Korea have achieved self-reliance in nuclear power technology. Pakistan Atomic Energy Commission (PAEC) is responsible for nuclear power development in Pakistan. At present, the country has two nuclear power plants with a total installed capacity of 462 MW including Karachi Nuclear Power Plant (KANUPP) and Chashma Nuclear Power Plant (CHASNUPP).

Table 2
Electricity demand and supply of Pakistan (in MW) from 2008 to 2020 (projected). *Source of Data*: [26].

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Existing generation	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903	15,903
Proposal/committed generation	530	4235	6574	10,115	10,556	13,307	13,520	14,607	16,134	18,448	18,448	18,448	18,448
Total existing/committed generation	16,484	20,138	22,477	26,018	26,459	29,210	29,423	30,510	32,037	34,351	34,351	34,351	34,351
Expected available generation	13,146	16,110	18,503	20,814	21,167	23,368	23,538	24,408	25,630	27,481	27,481	27,481	27,481
Demand (summer peak)	16,484	17,868	19,352	20,874	22,460	24,126	25,919	28,029	30,223	35,504	34,918	37,907	41,132
Surplus/deficit generation	−3338	−1758	−849	−60	−1293	−758	−2381	−3621	−4593	−8023	−7437	−10,426	−13,651

The 325 MW Chashma Nuclear Power Plant in the province of Punjab, the second nuclear power plant, constructed with the help of China National Nuclear Corporation (CNNC) was commissioned in September 2001. Both the power plants are working according to the safety standards set by Pakistan Nuclear Regulatory Authority [18,22,23].

5.1. Electricity demand & supply

An attempt has been made to illustrate past, present and future scenarios of country's electricity demand versus supply situation for the period of 2008–2020 (Table 2) [25]. There is an obvious deficit in the electricity supply and demand, which is being frequently controlled by peak-load management through load-shedding. Some of the key reasons behind the supply-and-demand situation in Pakistan include [26]:

- Fluctuations in the hydel electricity throughout the year because most of the installations are reservoir-based that depend on the climatic conditions.
- Decline in the actual available electricity from the four generation companies (GENCOs) well below the rated capacity with the passage of time as the result of mismanagement of fixed capital and lack of investment in new power plants.
- Fluctuations in the generation cost of furnace-oil-based thermal electricity (35% of the total electricity generation and governed by IPPs), because of the heavy reliance on the imported furnace oil over the passage of time.
- Huge transmission and distribution (T&D) losses because of inadequate and ageing infrastructure, resulting up to 20% losses of net electricity supply during 2010, and.
- Decline in the revenue collection mainly from public-sector consumers as the distribution companies (DISCOs) are not authorized to pass generation cost fully through to consumers.

Peak-load management increased from 2645 MW during 2007 to 6151 MW in 2011 (Fig. 11) [26]. The electricity demand and supply gap was improved marginally in 2011 from 34.7% to 33.2%. The average off-peak season (August to February) shortfall decrease to 2500 MW in 2011 as compared to 3000 MW in 2010; while, the average shortfall during peak season (March to July) improve from 3800 MW in 2010 to 3300 MW in 2011. As a result of these electricity demand-supply shortfalls, the average urban load-shedding was between 4 and 6 h daily in 2011. But in the rural areas of Pakistan, the load-shedding increased sharply to the level exceeding 10 h daily with frequent incidents of supply interruptions.

6. Status of renewable energy in Pakistan

The past decade has seen a worldwide realization in the use of renewable energy technologies. The World Summit for Sustainable Development (WSSD) in Johannesburg attempted to set targets



Fig. 12. Satellite map of Pakistan showing geomorphic features of Pakistan. *Source*: ESRI.

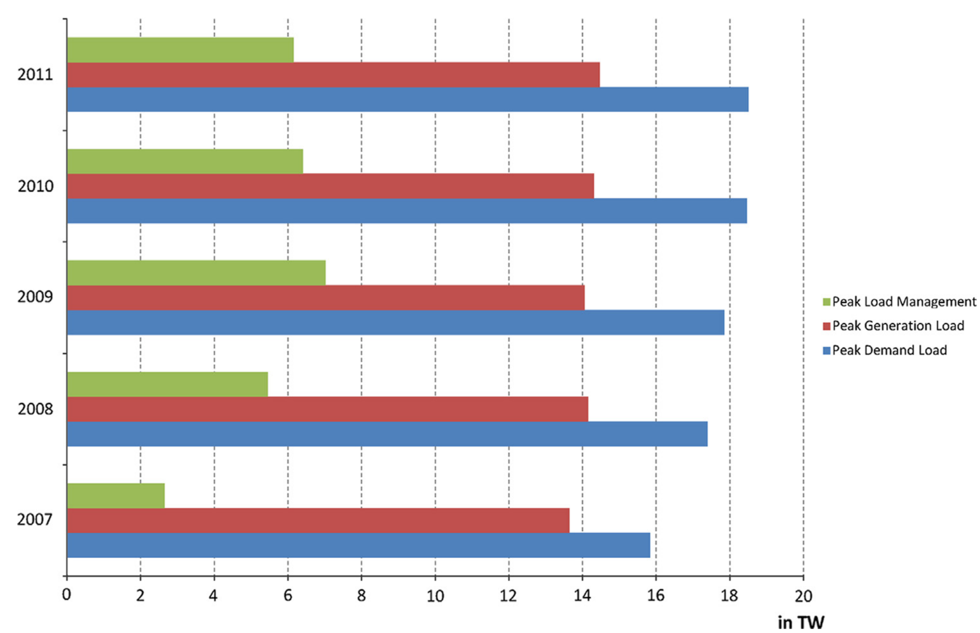


Fig. 11. Peak electricity demand, generation and load management in Pakistan from 2007 to 2011 (in TWh). *Data source*: [26].

for renewable energy in the energy mix of the world [16]. Major renewable energy resources include hydel, solar, wind, biomass, geothermal, sea-wave, Hydrogen cell energy, etc. Most of the renewable energy sources in Pakistan can at best be termed as at experimental or initial stages of development. As of today, the renewable technologies have not made any notable contribution to the national energy supplies except the hydel energy.

Pakistan has a large resource-base for employing renewable energy for meeting its energy needs but the potentials of renewable energy sources in the country have not been properly explored and evaluated as yet. There are apparently large potentials of power generation from renewable sources such as wind, solar, biomass, geothermal, and tidal available in the country. In this connection, a concise survey and assessment has already been made [27].

In fact, geological and geomorphological features of Pakistan vary longitudinally as well as latitudinally as shown in Fig. 12 and affect the nature and the availability of renewable energy sources accordingly.

Northern area of Pakistan has high mountains covered with glaciers and river systems with turbulent flow. That area suits very well for the micro, macro and mega hydel energy procurement systems. Moreover, Pakistan has one of the largest irrigation networks in Punjab and Sindh plains, the low-head canal power generation technology can also be adopted over a very large region.

Likewise, Punjab and Sindh provinces have enormous agricultural and cattle-farming activities. The animal and agricultural waste can be utilized for the generation of electricity by adopting biogas and incineration technologies.

Down the coastal areas of Pakistan stretching over 1000 km have bright prospects for generation of electricity through exploitation of sea-waves along the coastal areas and tidal-waves along the creeks of Indus delta. It may be mentioned here that the tidal-wave impact has relatively very high energy trends in the creeks of Indus delta.

The mountainous belts of Sindh, Balochistan and N.W.F.P. provinces and Northern areas of the country have hot-springs right from the coastal region of Arabian Sea to the northern Himalayan-Karakoram ranges, which indicate wide prospects to generate electricity from these hydro-geothermal sources in the years to come [28].

The southern Indus basin and Thar Desert region inclusive of Karachi synclinoriumarea in Sindh province, Chagai Arc region and the Kharan–Panjgur tectonic depression in the western Balochistan province are also inferred as the potential areas for the hot dry-rock geothermal resources [29].

The solar and the wind are the most abundant renewable sources spread all over the country. Recently, solar energy technology has been adopted significantly in one or the other way in the country. However, it is at an early stage of development. In this connection, more intense research related to field data, their evaluation and adoption of technologies need to be adopted to acquire energy at a low cost.

Though Pakistan has apparently significant prospect for exploitation of wind energy to generate electricity but practically no accelerated progress has so far been made for the generation of commercial grid-connected electricity except community-level stand alone units in limited rural areas mostly along the coastal regions.

Till today, Pakistan is in earlier stages in using wind energy technology due to the lack of reliable and complete data on wind resources. At present, limited daily and monthly wind related data are available in the Meteorological Department, which are being collected at low altitudes with significant time gaps. In fact, the data related to higher altitudes and shorter intervals are needed to assess the technical feasibility and economic viability for the commercial wind power project(s). The available data seem useful in identifying sites where wind power potential could be re-accessed in detail. Currently, available data indicate that wind regimes in the coastal areas of Sindh and Balochistan provinces, some parts of the north mountainous areas and the Indus valley may have adequate wind velocities for enough duration to be used. Pakistan has apparently enough wind velocity for sufficient duration in the year which can be harnessed.

Table 3
Salient achievements of PCRET till June 2009.
Source of Data: [22,23].

Renewable energy technology	Units installed	Capacity	Houses electrified/ benefited
Microhydel power	404	5537 KW	50,000
Wind turbine (off-grid)	153	153 KW	1500 household
Solar thermal			
Water heater	61	400l/day	6100
Solar desalination plant	3	15Lit/day	3
Solar dehydrator	21	5230 kg	21
Kaplan turbine	1	50 KW	1
Solar cookers box type	896	-	906
Solar cell fabricates	10,069	10.06 KW	-
Solar module fabricated	1137	1.12 KW	-
PV System	78	78 KW	730 mosques/schools
Biomass energy			
Cook stoves	70,100	–	70,100
Biogas	3824	13,425 CM3/	3824

By the end of 2009, the only significant milestone for the generation of electricity on the commercial or grid-connected scale through the exploitation of renewable sources was the installation of 6 MW wind farm at Jhimpir, 70 km northeast of Karachi city in Sindh province [30]. This wind farm was completed on October 15, 2008 by a local subsidiary of Turkish company named Zorlu Enerji Pakistan. The farm consists of five 1.2 MW gearless VENSYS-62 wind turbines and was conned to the national electricity grid in mid of 2009.

Since 2001, the Pakistan Council for Renewable Energy Technologies (PCRET) remains the focal point for the activities related to development and promotion of renewable energies in Pakistan after its inception by merging the National Institute of Silicon Technology (NIST) and Pakistan Council for Appropriate Technologies (PCAT) [22,31]. The main activity regime for PCRET circles around the installation and promotion of renewable energy sources on community level. Table 3 shows a brief of the achievements of PCRET regarding the renewable technologies based product disseminated to the community during 2009–2010 [23].

During 2010–2011, no major achievement was made by public as well as private sector for the development and/or installation of renewable based energy generation plants. Few community based projects were completed by PCRET and are as follows [18]:

- Six hundred photovoltaic (PV) modules were manufactured with the total generation capacity of 14 KW.
- A photovoltaic unit of 10 KW was installed in a public-sector office for basic electricity purpose.
- One hundred solar water heaters were installed under PCRET-MILTRONICS joint venture.
- Fourteen solar concentrators were fabricated and disseminated for public sector.
- Six box-type solar cookers were disseminated publically.
- Eighty-five fuel efficient biomass energy based cook stoves were disseminated throughout the country during 2010–2011, making it about 100,000 units of these fuel efficient stoves disseminated till yet.
- One thousand biogas plants of 5 m^3 capacity were installed with an annual production of 1.94 million m^3 of biogas, 1.6 million Kg of fertilizer and 4 million Kg of CO_2 abatement.
- Thirty biogas plants of commercial size from 50 to 250 m^3 were installed.

- Ten micro-hydel power plants with the total generation capacity of 112 KW were installed to provide electricity to 949 rural houses.
- A 7.5 KW micro-hydel plant was developed and installed in agricultural canal at Taxila, Punjab.

7. Discussion

The assurance to the economic sustainability of any country depends on the stable availability of its energy sources in proportion to the increasing rate of population, urban & industrial growths; the efficiently & strictly implementing of rules & regulations related to national energy planning, operational & management efficiency, the priority willingness, vision and loyalty of the national leadership and sincerity of the national and international investors, the funding agencies and the controlling leaders of the global developments, etc. In the case of Pakistan, the above imperative conditions, required for the energy-based economic up-rise of the peoples of the country, were disappointing since long [25], and are presently very repulsive.

Pakistan, despite the enormous potential of its indigenous energy resources, remains energy-deficient, because of the conventional priority to rely heavily on irrational imports of the petroleum products and rental/purchasing power options from neighboring countries to satisfy its need. Though, the thermal power-generating capacity was apparently increased on high price during 1990s due to the investment of the foreign Independent Power Producers (IPPs), but that could not be sustained and gradually collapsed on one or the other pretexts. On the other hand, other conventional energy sources, like coal, hydel, nuclear and multi-disciplinary renewable options, have not been given due considerations due to the national as well as international time-wasting dialogues on crosscutting policies and interests.

Contrary to the energy claims by the high ranking government spokesmen, IPPs and other national and international institutional players, Pakistan severely suffers from the massive electricity, natural gas, CNG, and LPG shortages. Prices of such basic commodities have inflated up not in percentage but in multifold beyond the purchasing power of a common man. Electricity generation has shrunk by up to 50% in recent years due to an over-reliance on fossil fuels (Oil & Gas) and neglecting the consisting development of other energy sources, presently which have resulted in 12–14 h load shedding in big cities and 16–18 h in small cities and almost the total darkness in several rural areas. Long queues are frequently observed to obtain CNG, LPG etc. even on monopolized high prices, the communities′ protest on roads and shutdown of industries (whether cottage and/or big ones). Purchasing of generators, ups-converters and other emergency electricity standby options and their daily recurrence expenditures have caused additional financial burden on communities.

The views of different energy experts, politicians, journalists, researches and planners have been integrated regarding the absolute deterioration of energy conditions, which have severely affected socioeconomics of country and each individual of the country except the elite class. Thus, the following factors seem to be the contributors to power crisis in the country:

- Lack of accountability regime and sense of crisis management crisis which is contributing in power crisis in the country.
- Lack of appropriate planning has led to today's energy crisis in Pakistan.
- Lack of seriousness and political will on part of government political leadership who despite clear warnings from WAPDA and international bodies, did not bother to give serious thought to plan future energy needs of the country.
- 'Adulteration' and 'pilferage' of fuel are major issues which results in billions of rupees loss to government.
- The main problem with Pakistan′s poor power generation is rising political instability, together with rising demands for power and lack of efficiency.
- Provincial and federal agencies, who are the largest consumers, often do not pay their bills.

Pakistan needs to look for alternate and innovative ways to end energy crisis in the country, like as follows:

- Emphasize on better policy decisions from concerned quarters.
- Demand stringent measures to reduce pilferages in fuel supply and transmission & distribution losses.
- Divert gas supply from inefficient plants to more efficient plants so that wastage of gas would be reduced and more megawatts of electricity can be produced.
- Interact more with the academia and industry to come up with collective measures in addressing energy crisis in Pakistan.
- Renewable energy options should be given real priority to develop indigenously, not the way as given considerations during the last decade(s).
- Bureaucratic and politics barriers should be ousted for development of new hydel-based energy generation options.
- Total dependence on oil & gas based power generation options should be lessened and be supplemented through the top priority development of the huge discovered coal deposit of Thar desert.

Pakistan has the third biggest coal reserve of the world [32] with the cumulative estimates of immense coal resources of more than 185.5 billion tones inclusive of Thar coal. The coal of Thar desert was discovered by the Geological Survey of Pakistan in 1991–92 and estimated reserves are 175 billion better quality lignite to bituminous coal with 1.75% low sulfur, 08.83% low ash, 48.57% moisture content, and 12,322 Btu average dry and ash-free heating value [33]. It is tested that the combustion of coal is found significantly safe for environmental concern as it produces little ash and low amount of SO_x (oxides of sulfur) gases [34]. Moreover, the ranking of coal has also been determined as lignite to sub-bituminous (a type of coal primarily used as fuel for steam-electric power generation) using standard classification of coal by American Standard and Testing Materials (ASTM). Recently, the Turkish investor stated too that the quality of Thar lignite is much better than the lignite being mined in many parts of the world [35].

In spite of better coal quality and huge reserves, one school of thought considers that the quality of Thar coal is uncertain and international donors are unwilling to pump money into such an environmentally damaging form of energy [36].

Several bodies and committees were formed and dismissed, some blocks allocated to foreign firms and then canceled. Sadly enough, it is still lying in deserts like a huge waste for various bureaucratic, economic and political reasons [37]. In most countries such as the US, China, Europe and India, coal has been and still is a great source of energy. Globally, the share of coal in power generation is 38%, compared to 0.1% in Pakistan. It is strange that while developed nations discourage power generation through coal in developing countries, whereas, none of them is willing to abandon its own coal plants. Considering the quantity and huge quantity, the Thar coal could have given the guarantee of self-sufficiency in energy for 200 years, if it would have been developed without wasting 20 years since its discovery.

8. Conclusions

Based on the critical review of the available conventional and nonconventional energy sources; the energy generation status;

the growth of population, urbanization and industrialization; the interactive past, present and future-anticipated efforts for the effective and efficient planning, development, management, transmission, distribution of the energy, it is concluded that:

- the progress of the responsible authorities of government, whether from public and private servant and/or electoral disciplines, to meet energy demand during the last more than one decade, particularly during the last 5 years, remained absolutely dissatisfactory and caused historic worse-possible shortfall of the energy in the country because of mainly mismanagement, lack of sincerity, half-hearted consideration to energy issues, financially self-oriented crosscutting interests, etc.
- no efforts were made for long-term energy projects/solutions except very short-term highly expensive rental energy generation options. These irrational rental energy producing options forced the Supreme Court of Pakistan to take ′somomoto′ action against the persons involved in this deal/project.
- as an end-results of the extremely poor energy concerns at the government level, the communities (total population) got severe energy load-shedding in each and every corner of the country collapsing the socio-economic structures and suffering from mental distresses.

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References

[1] Lehmann H. Overall energy policy and the advantages of renewable energy technology, Project Report # IV/95/42, Wuppertal Institute for Climate Energy & Environment, Berlin, 1995.
[2] Flavin C, Lenssen N. Power surge – guide to the coming energy revolution. New York: Norton & Co.; 1994.
[3] Elektrizitatswerke VD. Global consensus regarding the choice to adopt the energy generation sources – survey report. Germany: Institute for Praxisorientierte Sozialforschung; 1998.
[4] O.C.D.E., Vers une consommation durable des ménages – tendances et politiques dans les pays de l′OCDE, OECD Publishing, France, 2002.
[5] U.N.F.C.C.C., 2011, Kyoto Protocol [Online], United Nations Framework Convention on Climate Change, Available: ⟨http://unfccc.int/kyoto_protocol/items/2830.php⟩.
[6] W.E.C., Deciding the future – energy policy scenarios to 2050, World Energy Coulcil, London, 2007.
[7] Grob GR. The ISEO world sustainable energy mix scenario for environmentally compatible energy strategies. Geneva: ISEO Publication; 2004.
[8] Ooi KG, editor. Southeast Asia – a historical encyclopedia from angkor to east timor, Vol. III. California: ABC Clio; 2004.
[9] Ali S. Mixed-race post-race – gender new ethnicities and cultural practices. New York: Breg; 2003.
[10] F.B.S., Pakistan demographic survey – 2001, Federal Bureau of Statistics, Islamabad, 2002.
[11] F.B.S., Pakistan statistical yearbook – 2007, Federal Bureau of Statistics, Islamabad, 2008.
[12] F.B.S., Pakistan statistical yearbook – 2010, Federal Bureau of Statistics, Islamabad, 2011.
[13] F.B.S., Pakistan statistical yearbook – 2011, Federal Bureau of Statistics, Islamabad, 2012.
[14] F.D., Economic survey 2000–2001, Economic adviser's wing – Finance Division, Government of Pakistan, Islamabad, 2001.
[15] E.I.A., Annual energy outlook 2011, DOE/EIA-0383(2011), US Energy Information Administration, Washington, 2011.
[16] G.o.P, Policy for power generation projects, Government of Pakistan, Islamabad, 2002.
[17] U.N., Report of the world summit on sustainable development, UN Document # A/CONF.199/20, United Nations, New York, 2002.
[18] H.D.I.P., Pakistan energy yearbook – 2011, Hydrocarbon Development Institute of Pakistan, Islamabad, 2012.
[19] H.D.I.P., Pakistan energy yearbook – 2003, Hydrocarbon Development Institute of Pakistan, Islamabad, 2004.
[20] H.D.I.P., Pakistan energy yearbook – 2005, Hydrocarbon Development Institute of Pakistan, Islamabad, 2006.
[21] H.D.I.P., Pakistan energy yearbook – 2007, Hydrocarbon Development Institute of Pakistan, Islamabad, 2008.
[22] H.D.I.P., Pakistan energy yearbook – 2009, Hydrocarbon Development Institute of Pakistan, Islamabad, 2010.
[23] H.D.I.P., Pakistan energy yearbook – 2010, Hydrocarbon Development Institute of Pakistan, Islamabad, 2011.
[24] W.A.P.D.A., 2011, Water & Power Development Authority Pakistan [Online], Available: http://www.wapda.gov.pk.
[25] Shahbaz M. Electricity consumption financial development and economic growth nexus: a revisit study of their causality in Pakistan, MPRA Paper # 35588, Munich Personal RePEc Archive, Munich, 2011.
[26] S.B.P., Annual report 2010–2011 (State of the Economy), State Bank of Pakistan, Karachi, 2012.
[27] Zaigham NA, Nayyar ZA. Prospects of renewable energy sources in Pakistan. In: Khan HA, Qurashi MM, Hussain T, Hayee I, editors. Renewable energy technologies and sustainable development. Islamabad: COMSATS; 2005. p. 65–86.
[28] Zaigham NA, Nayyar. ZA, Hisamuddin N. Review of geothermal energy resources in Pakistan. Renew Sustain Energy Rev 2009;13:223–32.
[29] Zaigham NA, Nayyar ZA. Renewable hot dry rock geothermal energy source and its potential in Pakistan. Renew Sustain Energy Rev 2010;14:1124–9.
[30] Wikipedia, 2011, Jhimpir Wind Power Plant [Online], Available: ⟨http://en.wikipedia.org/wiki/Jhimpir_Wind_Power_Plant⟩.
[31] P.C.R.E.T., 2011, Pakistan Council for Renewable Energy Technologies [Online], Available: ⟨http://www.pcret.gov.pk⟩.
[32] Israr N. 2013, Energy crisis in Pakistan [Online], Available: ⟨http://www.hamariweb.com/articles/article.aspx?id=5938⟩.
[33] Fassett JE, Durrani NA. Geology and coal resources of the Thar Coal Field sindh province Pakistan: Department of Interior, USGS Open-File Report 94–167, 1994.
[34] Ilyas F. 2012, Thar coal quality, reactivity assessed [Online], Available: ⟨http://dawn.com/2012/12/10/thar-coal-quality-reactivity-assessed/⟩.
[35] Malik M. 2013, Energy crises result of faulty business model [Online], Available: ⟨http://app.com.pk/en_/index.php?option=com_content&task=view&id=233383&Itemid=2⟩.
[36] A.F.P, 2012, No end in sight for Pakistan′s energy crisis [Online], Available: ⟨http://tribune.com.pk/story/419175/no-end-in-sight-for-pakistans-energy-crisis/⟩.
[37] Bokhari A. 2010, Thar coal test burn [Online], Available: ⟨http://dawn.com/2010/12/06/thar-coal-test-burn-2/⟩.